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Gloster et al.

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(54) **SYSTEMS, STRUCTURES AND ASSOCIATED PROCESSES FOR INLINE ULTRASONICATION OF INK FOR PRINTING**

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(22) Filed: **Jun. 7, 2013**

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B41J 2/17 (2006.01)

(52) **U.S. Cl.**
CPC . ***B41J 2/1707*** (2013.01); ***B41J 2/19*** (2013.01)

(58) **Field of Classification Search**
CPC B41J 2/19
USPC 347/92
See application file for complete search history.

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Ultrasonic Cleaning Primer, copyright Branson Ultrasonics Corporation 1998 (“Branson”) (http://www.aqueoustech.com/aqueous%20university/knowledge-base/industry/Ultrasonic%20Cleaning%20Primer.pdf).*

* cited by examiner

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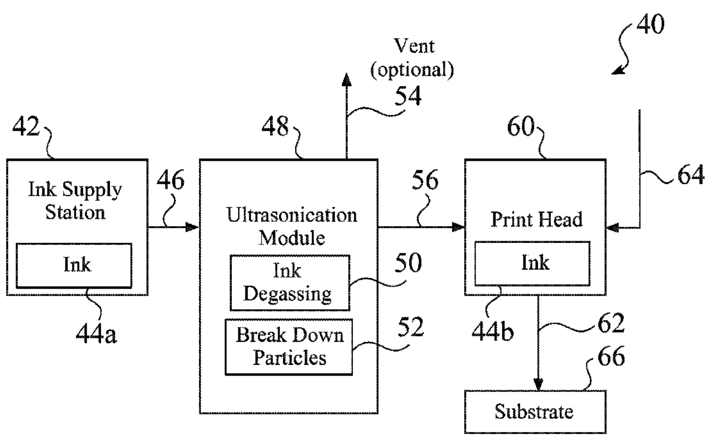
(57) **ABSTRACT**

Enhanced printing systems, structures, and processes provide ultrasonication of ink, such as to degas the ink, and/or to maintain the size of particles within the ink. At least one ultrasonic module, such as comprising any of an ultrasonic probe or an ultrasonic bath, is located within an ink delivery system. Ink is delivered to the ultrasonic module, and ultrasonic energy is applied to the ink, such as at a sufficient level and duration to degas the ink, and/or to reduce the size of particles within the ink. In some embodiments, the particles may be agglomerates, wherein the applied energy is configured to reduce the size of the agglomerates to a size that can be jetted through the print head. In other embodiments, the particles may be metallic particles, wherein the applied energy is configured to create smaller metallic particles that can be jetted with the ink through the print head.

24 Claims, 8 Drawing Sheets



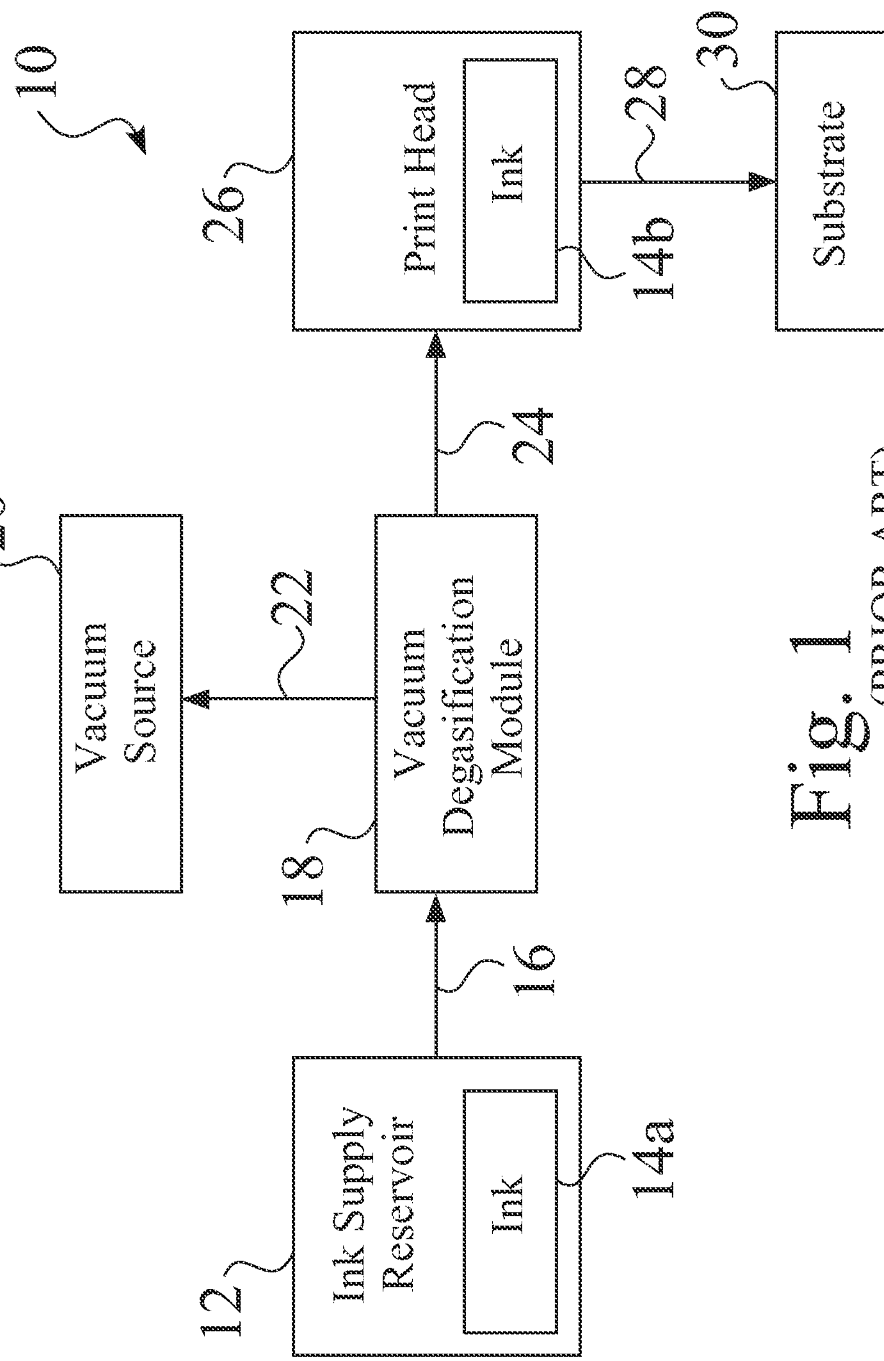


Fig. 1
(PRIOR ART)

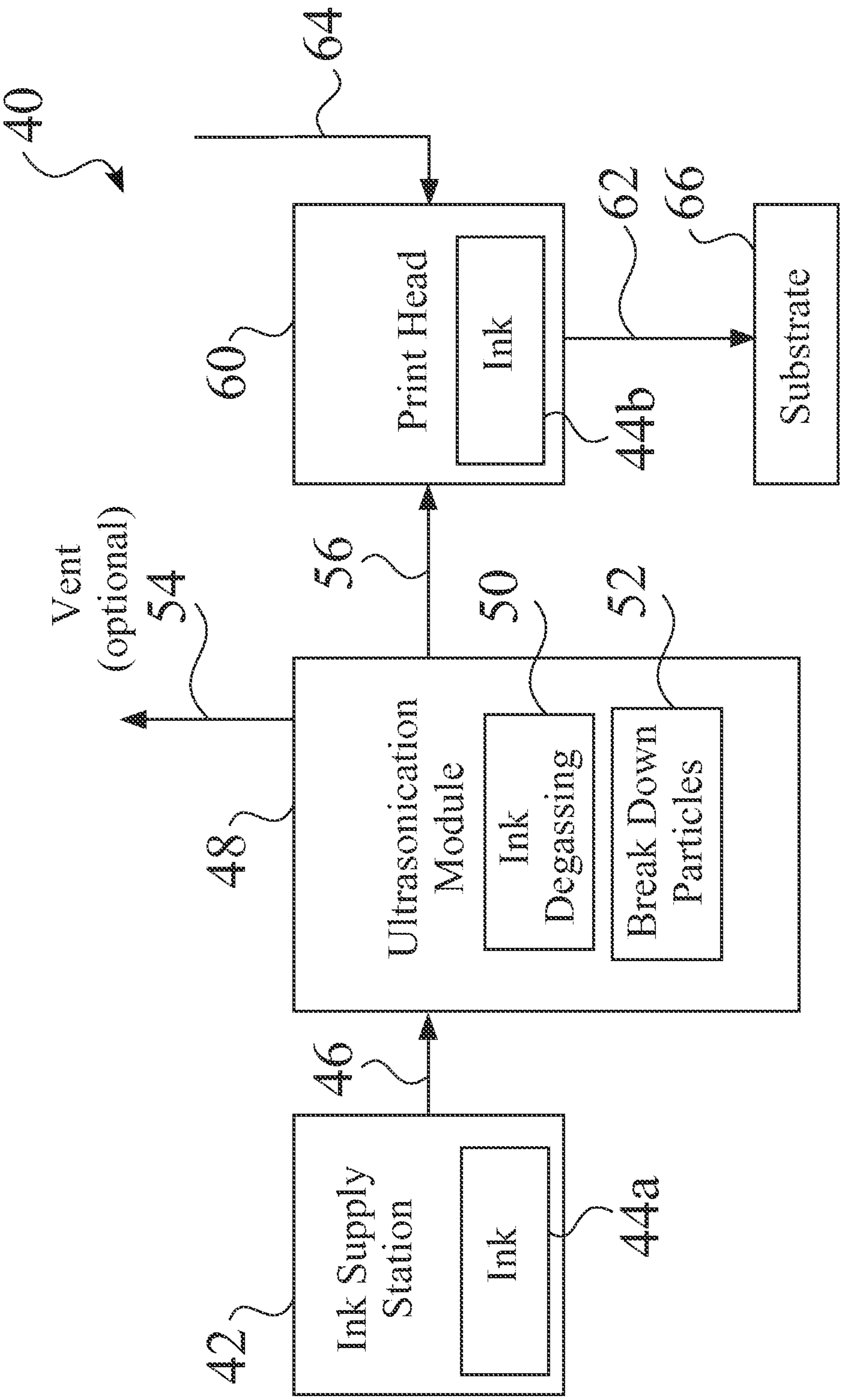

40
64
Print Head
Ink
60
44b
62
66
Substrate
Vent (optional)
54
56
50
52
Ultrasonication Module
Ink Degassing
Break Down Particles
48
46
Ink Supply Station
Ink
42
44a

Fig. 2

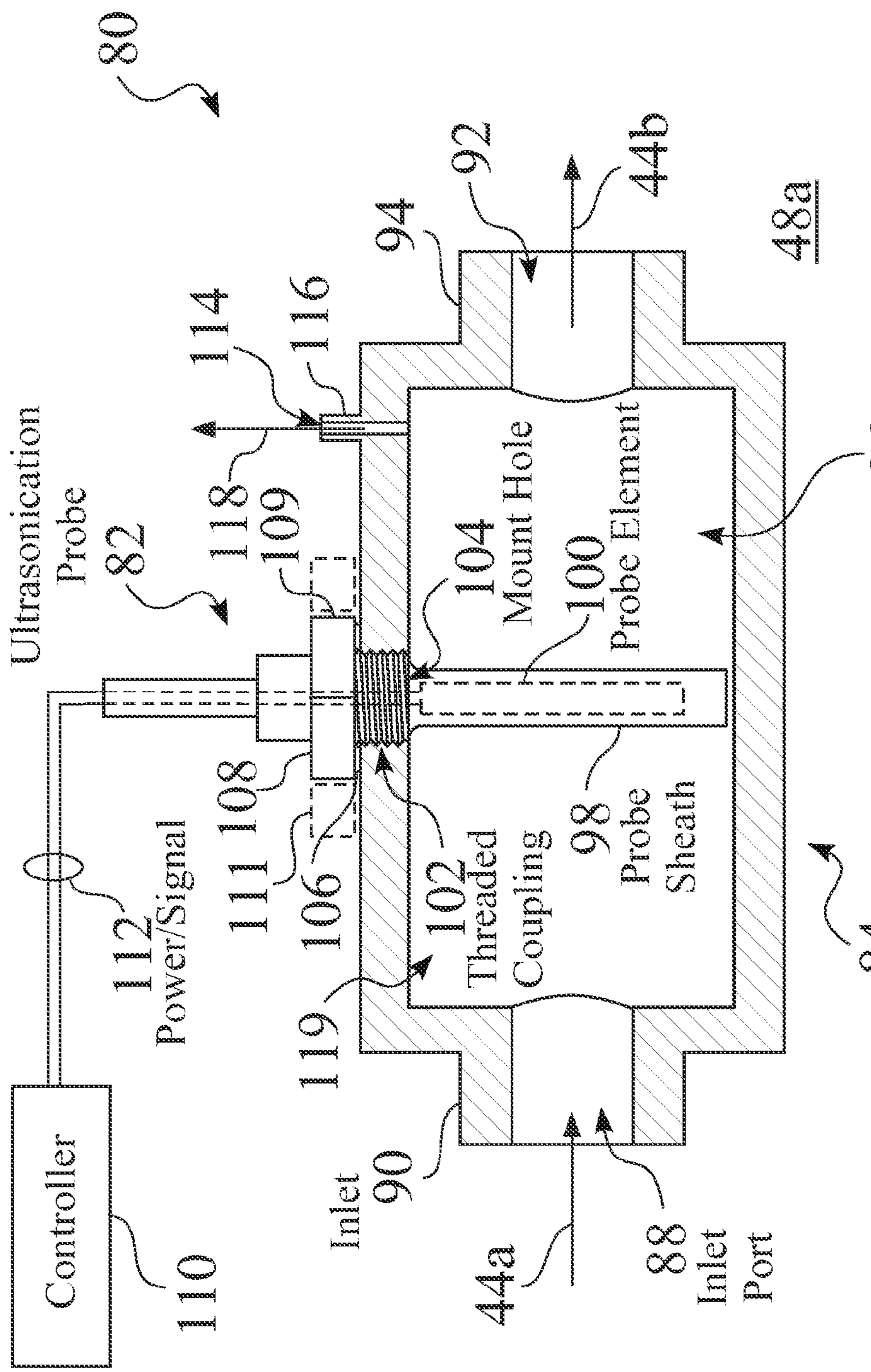

80
Ultrasonication Probe
82
Controller
110
112
Power/Signal
111
108
109
118
114
116
106
119
102
Threaded Coupling
104
Mount Hole
100
Probe Element
98
Probe Sheath
94
92
44b
48a
86
84
Inlet
90
44a
88
Inlet Port

Fig. 3

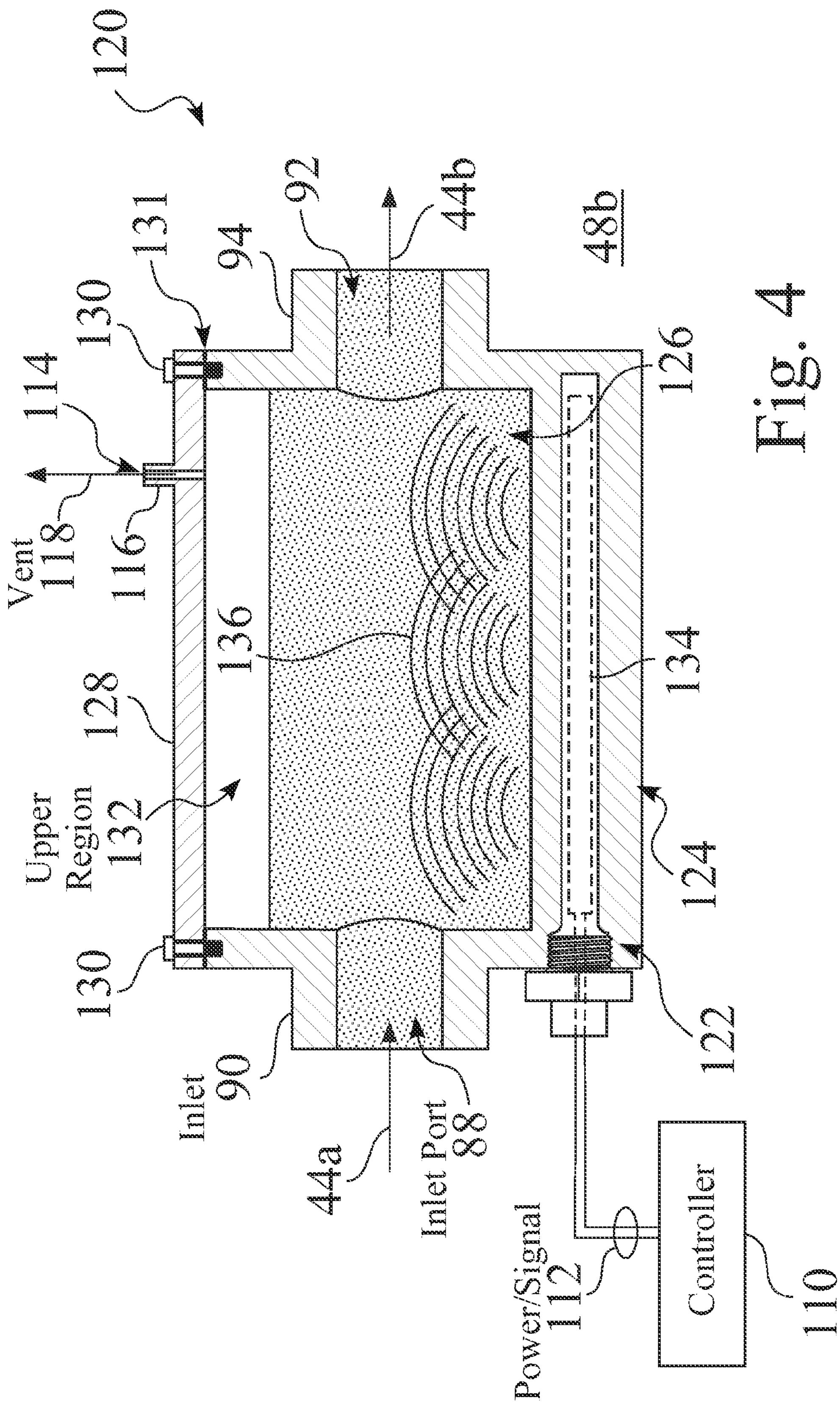

120
131
130
94
92
44b
48b
114
Vent
118
116
128
136
126
134
Upper
Region
132
124
130
Inlet
90
44a
Inlet Port
88
122
Power/Signal
112
Controller
110

Fig. 4

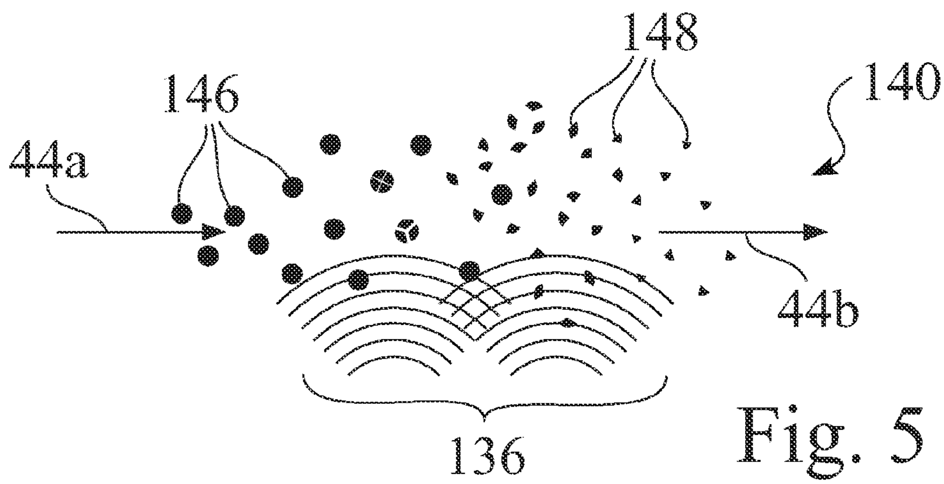


Fig. 5

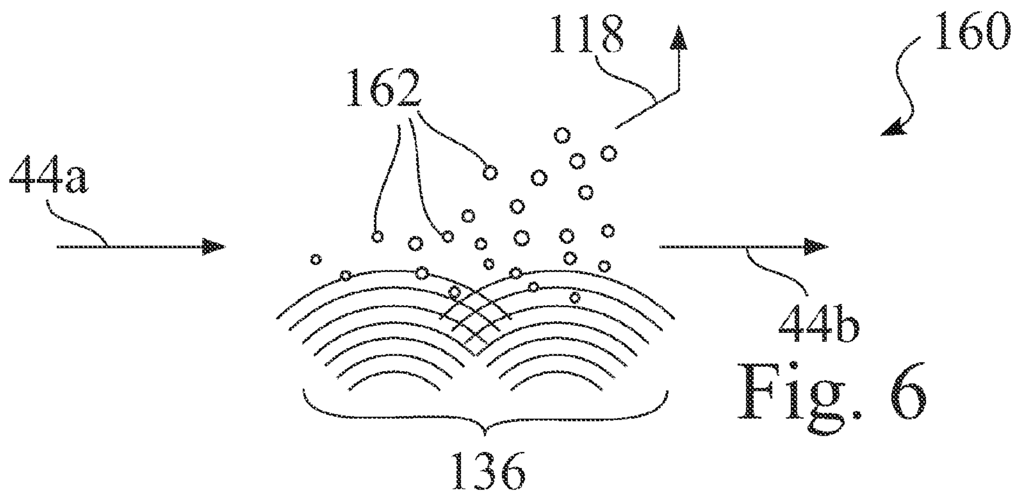


Fig. 6

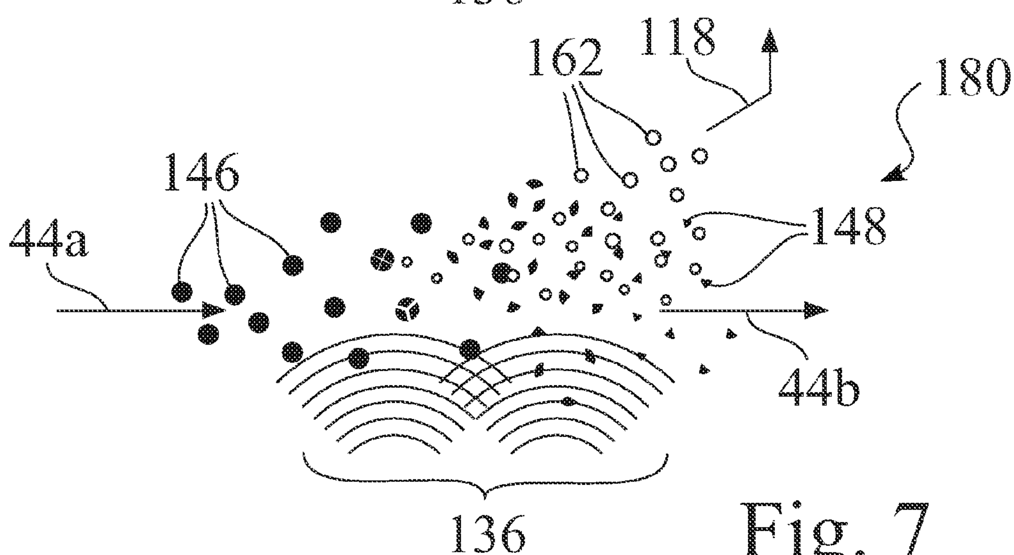


Fig. 7

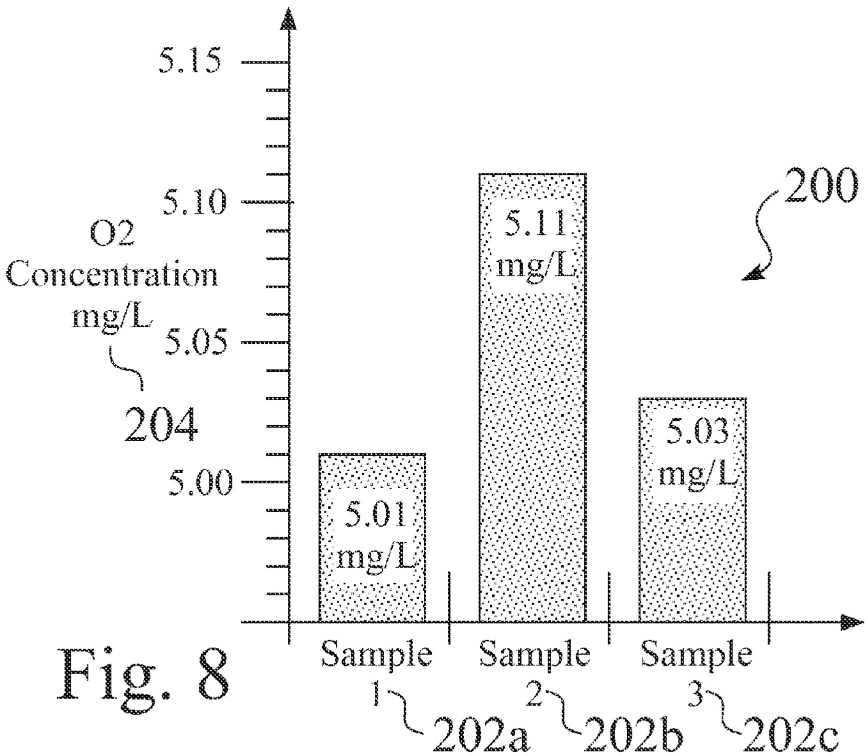

5.15
5.10
5.05
5.00
O2
Concentration
mg/L
204
200
5.01
mg/L
5.11
mg/L
5.03
mg/L
Sample
1
202a
Sample
2
202b
Sample
3
202c

Fig. 8

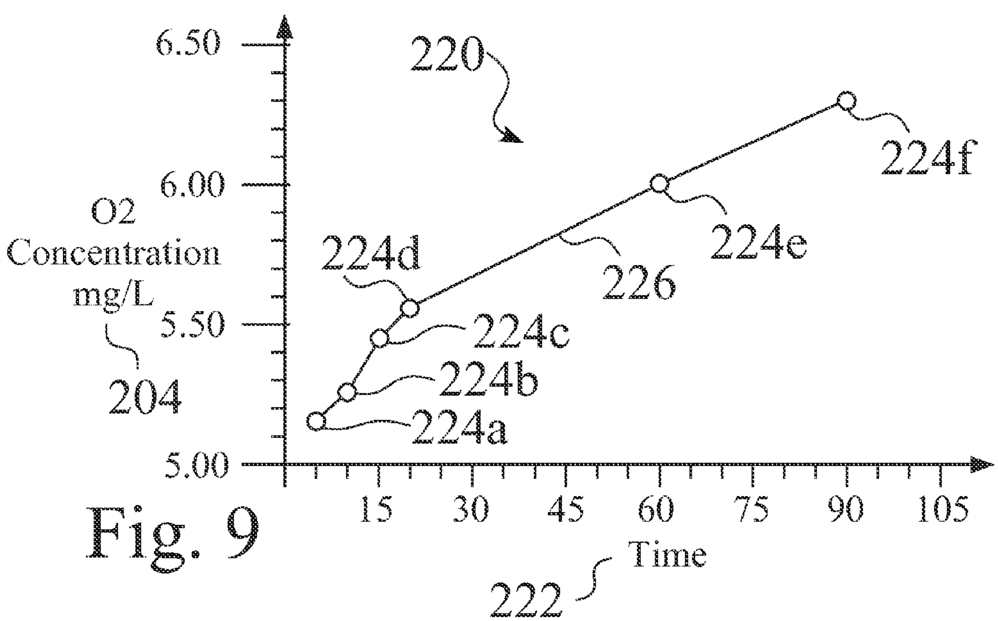

6.50
6.00
5.50
5.00
O2
Concentration
mg/L
204
220
224a
224b
224c
224d
224e
224f
226
15
30
45
60
75
90
105
Time
222

Fig. 9

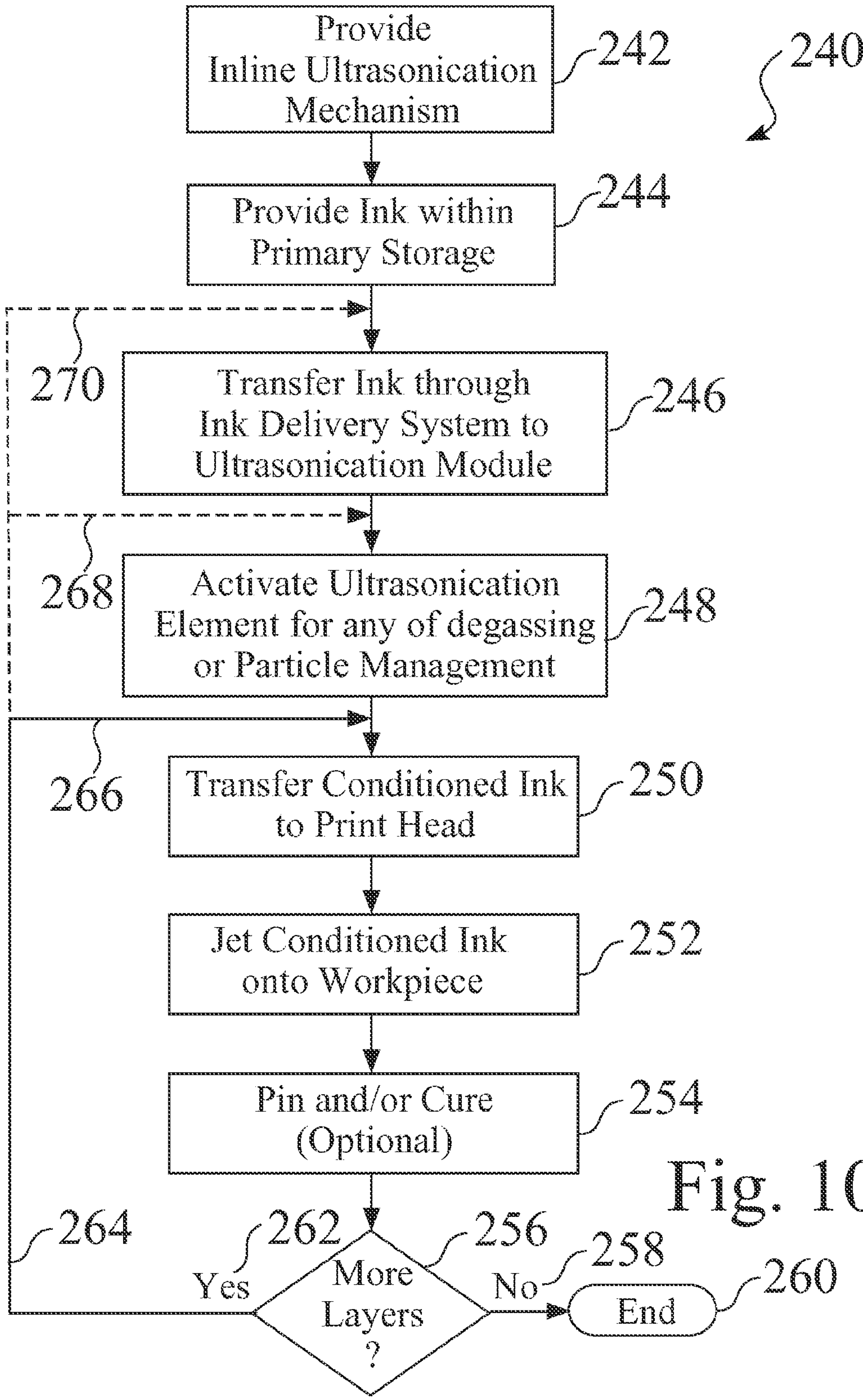

Provide
Inline Ultrasonication
Mechanism
242
240
Provide Ink within
Primary Storage
244
270
Transfer Ink through
Ink Delivery System to
Ultrasonication Module
246
268
Activate Ultrasonication
Element for any of degassing
or Particle Management
248
266
Transfer Conditioned Ink
to Print Head
250
Jet Conditioned Ink
onto Workpiece
252
Pin and/or Cure
(Optional)
254
264
262
Yes
More
Layers
?
256
No
258
End
260

Fig. 10

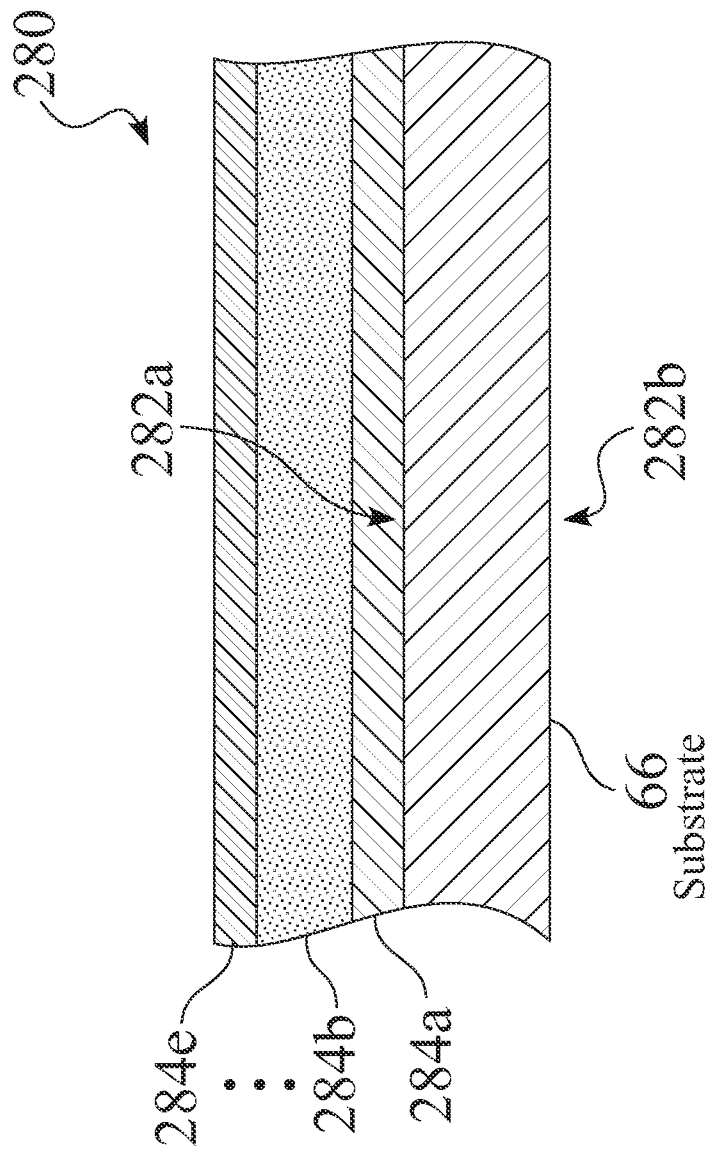


Fig. 11

SYSTEMS, STRUCTURES AND ASSOCIATED PROCESSES FOR INLINE ULTRASONICATION OF INK FOR PRINTING

FIELD OF THE INVENTION

The invention relates to the field of printing systems, structures, and associated processes. More particularly, the invention relates to systems, structures and processes that apply ultrasonic energy to liquid ink.

BACKGROUND OF THE INVENTION

Gas located within a fluid is compressible. Within a printing system, if a fluid ink contains one or more gasses, fluid ink to be ejected under pressure from an ink nozzle can therefore be compressed, due to the presence of gas, such that the ink may not jet correctly. Therefore, the presence of gas in a fluid ink that is intended for pressurized ejection reduces the reliability of producing an ejected droplet. In many such scenarios, the ink does not jet at all. Therefore, the presence of gas in a liquid ink can have a very large negative impact upon ink jetting, such as but not limited to the loss of printed material, which can be both costly and frustrating.

Vacuum degasification has previously been used in some printing systems. FIG. **1** is a schematic view of an exemplary conventional exemplary printing system **10** having inline vacuum degasification. Ink **14***a*, such as stored within an ink supply reservoir **12**, e.g. a cartridge or tank, is transported **16** through a vacuum degasification module **18**. A vacuum source **20**, e.g. a pump or venturi, is also typically connected **22** to the vacuum degasification module **18**, which applies a vacuum to the ink **14***a* within the vacuum degasification module **18**, thereby extracting one or more gasses from the incoming ink **14***a*, producing degassed ink **14***b*, which is delivered **24** to a print head **26**, wherein the print head **26** is configured to controllably jet **28** the degassed ink **14***b* onto a substrate **30**.

Some conventional vacuum degassing modules are available through DIC Corporation, of Tokyo, Japan, wherein different modules are specified based on the type of ink to be jetted, the capacity, and the desired level of degassing. Other degassing devices are available through Membrana Inc., of Charlotte, N.C. A wide range of filter capsules is also available through Pall Corporation, of Port Washington, N.Y.

While vacuum degasification has previously been used to remove some gases from ink, such systems are often complex, and typically require a pressure source or a vacuum source.

It would therefore be advantageous to provide a mechanism that is configured to remove gasses that may be present in an ink at any point within a printing system, without requiring vacuum degasification and related hardware. The development of such a system or structure would be a major technological breakthrough.

Sonication has been used previously in applications other than printing, to break down larger particles into smaller particles. For example, ultrasonic energy has previously been used to break down kidney stones in a medical environment.

Besides problems with resident gasses, particulates in an ink supply have also posed numerous problems. For example, nozzle clogging due to particulates is a common print head failure mode in printing systems. Particulates, such as but not limited to agglomerated particles, are often present within an ink, or may occur within an ink delivery system, in a printing environment. While relatively small particles may pass though an ink delivery system, and be jetted through an inkjet print head along with the liquid ink, larger particles can easily build up within ink delivery circuits, and often clog print heads and associated pathways, e.g. within one or more nozzle plates.

It would therefore be advantageous to provide a mechanism and associated process that is capable of breaking down the size of particulates that may be present in an ink, at any point within a printing system, to prevent fouling. The development of such a system, structure, and associated process would provide a major technological advance.

In addition, while prior vacuum degasification systems may be configured to remove resident gases from an ink supply, such systems do not address other solids that may be present in the ink, such as agglomerated pigments.

It would therefore be advantageous to provide a system, structure, and associated process that is capable of both removing resident gases from an ink supply, and maintaining the size of particulates in the ink supply, at any point within a printing system. The development of such a system, structure, and associated process would constitute a further major technological breakthrough.

SUMMARY OF THE INVENTION

Enhanced printing systems, structures, and processes provide ultrasonication of ink, such as to degas the ink, and/or to maintain the size of particles within the ink. At least one ultrasonic module, such as comprising any of an ultrasonic probe or an ultrasonic bath, is located within an ink delivery system. Ink is delivered to the ultrasonic module, and ultrasonic energy is applied to the ink, such as at a sufficient level and duration to degas the ink, and/or to reduce the size of particles within the ink. In some embodiments, the particles may be agglomerates, wherein the applied energy is configured to reduce the size of the agglomerates to a size that can be jetted through the print head. In other embodiments, the particles may be metallic particles, wherein the applied energy is configured to create smaller metallic particles that can be jetted with the ink through the print head.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of an exemplary prior art printing system having inline ink vacuum degassing;

FIG. **2** is a schematic diagram of an exemplary enhanced printing system having ink ultrasonication;

FIG. **3** is a detailed schematic view of an ultrasonication probe assembly associated with an ink transport or storage system;

FIG. **4** is a detailed schematic view of an ultrasonication bath assembly associated with an ink transport or storage system;

FIG. **5** is a schematic view of ultrasonication used to break down particles;

FIG. **6** is a schematic view of ultrasonication used to degas ink;

FIG. **7** is a schematic view of ultrasonication used for both particle size reduction and degassing of ink;

FIG. **8** is a chart that shows exemplary oxygen concentrations for three different ink samples, immediately after an interval of applied ultrasonic energy, for one embodiment of an ultrasonic bath;

FIG. **9** is a chart showing oxygen concentration of an ink sample as a function of time after stopping an application of ultrasonic energy;

FIG. **10** is a flowchart of an exemplary process for ultrasonication of ink that is applied to create one or more layers on a work piece, e.g. a substrate; and

FIG. **11** is a partial cross section of an exemplary substrate having one or more jetted layers, wherein at least one of the layers has had ultrasonication applied to the ink before jetting onto the substrate.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. **2** is a schematic diagram of an exemplary enhanced printing system **40** having an ultrasonic module **48**, such as to ultrasonically degas **50** ink **44**, e.g. **44***a*, and/or to ultrasonically break down **52** particles **146** (FIG. **5**, FIG. **7**), e.g. agglomerates, metallic particles, or other solids **146**, which may be present within an ink **44***a*.

Ink **44***a*, such as stored within an ink supply station **42**, e.g. a reservoir, cartridge or tank **42**, is transported **46** through one or more ultrasonic modules **48**, such as past an ultrasonic probe assembly **48***a* (FIG. **3**), and/or through an ultrasonic bath assembly **48***b* (FIG. **4**). A vent **54** may preferably be provided, such as for an ultrasonic module **48***a* that provides degassing **50**, to extract one or more gasses **162** (FIG. **6**, FIG. **7**) that are outgassed from incoming ink **44***a*, producing degassed ink **44***b*. The resultant conditioned ink **44***b* may preferably be delivered **56** to or through a corresponding print head **60**, where the conditioned ink **44***b* may be jetted **62** or otherwise delivered onto one or more portions of a workpiece **66**, e.g. a substrate, such as in response to a signal **64**.

FIG. **3** is a detailed schematic view **80** of an ultrasonication probe assembly **48***a* associated with an enhanced printing system **40**. The exemplary ultrasonication probe assembly **48***a* seen in FIG. **3** comprises a probe housing **84** having a chamber **86** defined therein, an inlet **90** having a corresponding inlet port **88**, and an outlet **94** having a corresponding outlet port **92**.

The exemplary ultrasonication probe assembly **48***a* seen in FIG. **3** further comprises an ultrasonication probe **82**, which is affixed to the probe housing **84** and extends into the chamber **86**. The exemplary ultrasonication probe **82** comprises a probe sheath **98** that extends into the ink chamber **86** from a threaded coupling **102**, which is threadably engaged through a threaded probe mount hole **104**. The exemplary ultrasonication probe **82** may further comprise a landing **108**, such as having opposing faces **109**, for engagement by a tool **111** that is configured to fasten the ultrasonication probe **82** to the housing **84**. A washer, gasket, or seal **106** may preferably be provided between the landing **108** and the housing **84**.

The exemplary ultrasonication probe **82** seen in FIG. **3** further comprises an ultrasonic probe element **100**, such as located within the probe sheath **98**, wherein the probe element **100** is connected **112** to a controller **110**, such that the ultrasonication probe **82** may be controllably powered to provide ultrasonic energy **136** (FIG. **4**) such as in the range of about 20 kHz to 400 kHz. In operation, when ink **44***a* enters the chamber **86** through the inlet port **88**, the ultrasonic probe element **100** may be powered to ultrasonically treat the incoming ink **44**.

The exemplary ultrasonication probe assembly **48***a* seen in FIG. **3** may further comprise a vent **116** having a gas outlet port **114**, through which any gas **162** released though degassing **50** may be vented **118**. The exemplary vent **116** and corresponding gas outlet port **114** seen in FIG. **3** is located toward an upper region **119** of the chamber **86**, such that gasses **162** may be vented **118**, without loss of ink **44**, e.g. **44***a* or **44***b*.

FIG. **4** is a detailed schematic view **120** of an exemplary ultrasonication bath assembly **48***b* associated with an enhanced printing system **40**. The exemplary ultrasonication assembly **48***b* seen in FIG. **4** comprises an ink bath housing **124** having a chamber **126** defined therein, an ink inlet **90** having a corresponding inlet port **88**, and an ink outlet **94** having a corresponding outlet port **92**. The exemplary ultrasonication bath assembly **48***b* seen in FIG. **4** also comprises a tank cover **128**, which may be fastened **130** to the upper region **132** of the ink bath housing **124**. A seal **131** may also be provided between the tank cover **128** and the tank housing **124**, around the perimeter of the tank chamber **126**.

The exemplary ultrasonication probe assembly **48***b* seen in FIG. **4** further comprises an ultrasonication module **122** that is affixed to the ink bath housing **124**. The exemplary ultrasonication module **122** includes an ultrasonic probe element **134**, which is connected **112** to a controller **110**, wherein the ultrasonication module **122** may be controllably powered to provide ultrasonic energy **136** to ink **44***a* within the chamber **126**. While the exemplary ultrasonication probe assembly **48***b* provides a schematic depiction of a corresponding ultrasonication mechanism **122**, it should be understood that many configurations may be provided, such as to apply ultrasonic energy **136** from one or more directions into the chamber **126**. In operation, when ink **44***a* enters the chamber **126** through the inlet port **88**, the ultrasonic element **134** may controllably be powered to ultrasonically treat **136** the incoming ink **44***a*.

The volume of the chamber **126** may preferably be configured to allow sufficient storage of the ink **44** for a suitable time period, such as to provide an adequate residence time for any of ink degassing **50** or breakdown **52** of particles **146**.

The exemplary ultrasonication probe assembly **48***b* seen in FIG. **4** may further comprise a vent **116** having gas outlet port **114**, through which any gas **162** (FIG. **6**, FIG. **7**) released though degassing **50** may be vented **118**. The exemplary vent **116** and corresponding gas outlet port **114** seen in FIG. **3** is located toward an upper region **132** of the chamber **126**, which may preferably be integrated with a tank cover **128**, wherein released gasses **162** may be vented **118**, without loss of ink **44**, e.g. **44***a* or **44***b*.

FIG. **5** is a schematic view **140** of ultrasonic energy **136**, e.g. about 20 kHz to 400 kHz, used to break down **52** particles **146**, e.g. agglomerates, metallic particles, or other solids **146**, which may be present within an incoming ink **44***a*. As seen in FIG. **5**, incoming ink **44***a* may contain one or more types of particles **146**.

For example, the incoming ink **44***a* may contain undesired agglomerates **146**, wherein the ultrasonic energy **136** may preferably be applied to break down and/or maintain the size of the agglomerates **146**, e.g. to a level wherein the particles **146** may preferably be filtered or delivered, e.g. jetted **62**.

In some embodiments, at least a portion of the particles **146** may comprise intended particles **146**, e.g. metallic particles or pigments, wherein the ultrasonic energy **136** may preferably be applied to prepare the size of the pigments **146** for any of transport **56** (FIG. **2**) or delivery, e.g. jetting **62** (FIG. **2**). For example, metallic particles **146** may controllably be reduced in size to provide a desired metallic ink **44***b*. As well, the level of applied ultrasonic energy **136** may preferably be controllable **110**, e.g. in magnitude or time, to produce different ink characteristics, e.g. such as but not limited to any of color, gloss, or opacity. The level of applied ultrasonic energy **136** may also preferably be controllable **110** to provide different ink characteristics based on different intended substrates **66**, e.g. different paper types, finishes, films, surfaces, or any combination thereof. Furthermore, the applied ultrasonic energy **136** may also be controllable **110** based on other inputs, e.g. such as but not limited to temperature, humidity, or based on information related to the ink or carrier. For example, a product code may provide input that is associated with ultrasonic energy **136** that is required to break down included particles.

While the ultrasonication module **48** may be located at any point within a printing system **40**, the ultrasonic energy **136** may preferably be applied just prior to printing **62**. As well, ultrasonication energy **136** may preferably be applied to an ink **44***a* before delivery to a printing system **40**, e.g. before delivery to the ink supply station **42**, such as to maintain or prepare a new ink **44***a*, and/or to condition an older ink **44***a*.

FIG. **6** is a schematic view **160** of ultrasonication energy **136** used to degas **50** ink **44***a*, wherein the gas **162** may typically comprise one or more gasses **162**, such as but not limited to any of oxygen, air, water vapor, volatile carriers, or other resident gases **162**.

FIG. **7** is a schematic view **180** of ultrasonication energy **136** used for both particle size reduction and degassing of ink **44***a*. As seen in FIG. **2**, FIG. **3**, and FIG. **4**, the exemplary enhanced printing system **40** may readily be configured to provide both ink degassing **50** and ink particle management **52**, and thus can be implemented to provide comprehensive conditioning of ink **44** at one or more points in an ink delivery system.

Exemplary Performance of Degassing with Applied Ultrasonic Energy. An ultrasonic bath assembly **48***b* was used to test the degassing performance of an ultrasonic mechanism **48**, wherein the ultrasonic bath assembly **48***b* comprised a Model 3510 Branson Ultrasonic Cleaner, available through Branson Ultrasonics Corp., of Danbury Conn., which has an overall size of 16 inches×12 inches×14.5 inches, a tank size of 11.5 inches×6 inches×6 inches, a weight of 12 pounds, and a frequency of 40 kHz.

FIG. **8** is a chart **200** that shows exemplary oxygen concentrations **204** for three different ink samples **202**, e.g. **202***a*-**202***c*, immediately after a 15 minute interval of applied ultrasonic energy **136**, for one embodiment of an ultrasonic bath **44***b*. As seen in FIG. **8**, a first sample **202***a* of ink **44** had an oxygen concentration of 5.01 mg/L, a second sample **202***b* of ink **44** had an oxygen concentration of 5.11 mg/L, and a third sample of ink **44** had an oxygen concentration of 5.03 mg/L. As seen in FIG. **8**, the application of ultrasonic energy **136** in an ultrasonic bath **44***b* provides substantial removal of resident oxygen **162** within an ink **44**.

FIG. **9** is a chart **220** showing oxygen concentration **204** of an ink sample **44** as a function of time **222** after stopping the application of ultrasonic energy **136**. A first data point **224***a* shows an ink concentration level of 5.14 mg/L at a time **222** of 5 minutes. A second data point **224***b* shows an ink concentration level of 5.24 mg/L at a time **222** of 10 minutes. A third data point **224***c* shows an ink concentration level of 5.44 mg/L at a time **222** of 15 minutes. A fourth data point **224***d* shows an ink concentration level of 5.56 mg/L at a time **222** of 20 minutes. A fifth data point **224***e* shows an ink concentration level of 6.01 mg/L at a time **222** of 60 minutes. A sixth data point **224***f* shows an ink concentration level of 6.31 mg/L at a time **222** of 90 minutes. Line **226** shown in FIG. **9** is a plot of approximated performance based on the measured results **224***a*-**224***f*.

As seen in FIG. **9**, an ink **44** that is degassed **50** slowly reabsorbs gasses **162**, if exposed to the gasses. In some printing system environments, therefore, it may be preferred to position an ultrasonic assembly **44** close to the corresponding print heads **62**, to avoid reabsorption of any gasses **162**.

FIG. **10** is a flowchart of an exemplary process **240** for the ultrasonic conditioning **136** of ink **44**, before application of the conditioned ink **44***b* to create one or more ink layers **284**, e.g. **284***a*-**284***e* (FIG. **11**) on a work piece **66**. As seen in FIG. **10**, one or more ultrasonication mechanisms **48**, e.g. such as but not limited to a probe assembly **48***a* or a bath assembly **48***b*, are provided **242** anywhere within an ink distribution system for a printer, as desired. Within an established enhanced system **40**, ink **44**, e.g. **44***a*, is provided **244** for one or more channels, e.g. CYMK, such as within primary storage stations **42**. In operation, the ink **44***a* is transferred **246** to the ultrasonication module **48**. The ultrasonication mechanism **48** is activated **248** as desired, such as for any of ink degassing **50**, particle management and/or particle preparation **52**, or any combination thereof. The conditioned ink **44***b* is then transferred **250** to one or more print heads **26**, where the conditioned ink **44***b* is controllably jetted onto the workpiece **66**, such as directly to the workpiece **66**, or onto a previously applied layer **284**.

While the exemplary embodiments disclosed herein generally describe application of ink onto a workpiece **62**, it should be understood that one more of the layers **284**, e.g. **284***a* (FIG. **11**), may be pinned or cured before the application of subsequent layers **284**, e.g. **284***b*-**284***e*. As further seen in FIG. **10**, if it is determined **256** that there are no **258** further layers **284** to be printed, the process ends **260**. If it is determined **256** that there is **262** at least one more layer **284** to be printed, the process returns **264**, such as shown at **266**, **268**, or **270**, as required, to proceed as necessary to print one or more additional layers **284**.

FIG. **11** is a partial cross section **280** of an exemplary substrate **66** having one or more jetted layers **284**, e.g. **284***a*-**284***e*, wherein at least one of the layers **284** has had ultrasonication energy **136** applied to the ink **44** before being applied to the substrate **66**. The exemplary substrate **66** seen in FIG. **11** comprises a first side **282***a*, and a second side **282***b* opposite the first side **282***a*, wherein the ink layers are applied to the first side **282***a*.

The application of ultrasonic energy **136** may preferably be used to condition a wide variety of inks **44**, such as but not limited to any of:

- undercoats or primer layers;
- one or more color layers (CMYK, spot colors, opaque inks, translucent inks, tinted inks, clear inks, etc.);
- intermediate coatings;
- outer protective layers; or
- any combination thereof.

The enhanced ultrasonication systems **40**, structures **48**, and processes **240** may preferably be configured to re-disperse large particles **146** that have agglomerated over time, as the formation of particle agglomerates or clusters causes jetting issues. The reduction and maintenance of particles **146** is particularly useful where materials are prone to settling due to their high density.

The enhanced ultrasonication systems **40**, structures **48**, and processes **240** are particularly advantageous for printing environments that may benefit from dual-capability, comprising both ink degassing **50** and particle maintenance and/or preparation **52**, e.g. for inkjet printing or for any type of printing.

The enhanced ultrasonication system **40** may preferably be configured to improve and maintain jet sustainability, by removing compressible gasses from an ink **44***a*. As the conditioned ink **44***b* is ejected from an inkjet nozzle, the prior removal of compressible gasses allows the conditioned ink **44***a* to be jetted efficiently.

As well, the enhanced ultrasonication systems **40**, structures **48**, and processes **240** may preferably be configured to efficiently break down, i.e. make smaller in size, pigment agglomerates **146**, such as to maintain sufficiently small particle sizes that easily and reliably flow through an inkjet print head, thus avoiding the clogging of nozzles, which can otherwise lead to a printer failure mode.

Furthermore, the enhanced ultrasonication systems **40**, structures **48**, and processes **240** may be configured to apply ultrasonic energy to inks **44***a* that intentionally contain particles, e.g. metallic flakes, wherein the ultrasonic energy **136** may be configured to produce a conditioned metallic ink **44***b* having small particles **146**, such as just prior to printing **62**.

The enhanced ultrasonication systems **40**, structures **48**, and processes **240** may readily be provided for a wide variety of printers, depending on the efficacy. As well, the enhanced ultrasonication systems **40**, structures **48**, and processes **240** may be applied retroactively to a wide variety of existing printers, such as to improve print quality and reliability. Furthermore, the integration of enhanced ultrasonication systems **40**, structure **48**, and processes **240** that manage particle size of added particulates, e.g. metals, may increase the functionality of existing printers, allowing them to readily integrate new and improved ink products, such as to produce a wider spectrum of printed output.

The enhanced ultrasonication systems **40**, structures **48**, and processes **240** can therefore be configured to improve the sustainability of print heads, e.g. **60**, and thus, of printer systems, e.g. **40**.

Although the enhanced ink ultrasonication systems, structures and methods of use are described herein in connection with printing systems, the structures and techniques can be implemented for a wide variety of applications and environments, or any combination thereof, as desired.

For example, the enhanced ink ultrasonication systems, structures and methods of use may alternately be implemented for degassing and/or particle control for other environments that use inks, or for the degassing and/or particle control of other liquid mixtures, such as but not limited to paints, fuels, lubricants, foods and/or drinks.

Accordingly, although the invention has been described in detail with reference to a particular preferred embodiment, persons possessing ordinary skill in the art to which this invention pertains will appreciate that various modifications and enhancements may be made without departing from the spirit and scope of the claims that follow.

What is claimed is:

1. A printing system for conditioning ink, comprising:
- an ink supply station for storing the ink;
- at least one print head;
- a delivery conduit comprising an ink chamber, said delivery conduit located between the ink supply station and the at least one print head; and
- at least one ultrasonication assembly located within the delivery conduit, and extending into the ink chamber;
- wherein the system is configured to deliver the ink from the ink supply station to the at least one ultrasonication assembly;
- wherein the at least one ultrasonication assembly is configured to apply ultrasonic energy to the ink to condition the ink; and
- wherein the system is configured to deliver the conditioned ink from the at least one ultrasonic assembly to the at least one print head;
- wherein the ink contains metallic particles, and wherein the at least one ultrasonication assembly is configured to reduce the size of the metallic particles before delivery of the conditioned ink to the print head, wherein the print head is configured to deliver the conditioned ink having the reduced metallic particles onto a work piece.

2. The printing system of claim **1**, wherein the ultrasonication assembly comprises an ultrasonic probe assembly.

3. The printing system of claim **1**, wherein the ultrasonic energy has a characteristic frequency range of about 20 kHz to 400 kHz.

4. The printing system of claim **1**, wherein the ink contains dissolved gas, and wherein the at least one ultrasonication assembly is configured to degas the ink, to improve jetting of the ink from the print head onto a work piece.

5. The printing system of claim **1**, wherein the ink contains agglomerated particles, and wherein the at least one ultrasonication assembly is configured to reduce the size of agglomerated particles.

6. The printing system of claim **5**, wherein the reduced size of the agglomerated particles prevents clogging of at least a portion of the print head.

7. The printing system of claim **1**, wherein the at least one ultrasonication assembly is configured to contain the ink for a time period that is sufficient for any of ink degassing or breakdown of particles.

8. The printing system of claim **1**, wherein the ink contains dissolved gas and particles, and wherein the at least one ultrasonication assembly is configured to degas the ink and to reduce the size of the particles.

9. An apparatus for conditioning ink, comprising:
- a body comprising
  - a chamber defined therein,
  - an inlet port extending into the chamber for receiving ink from an ink supply station, and
  - an outlet port extending from the chamber for transporting ink from the chamber to a print head; and
- an ultrasonication mechanism comprising an energy source extending into the chamber for delivering ultrasonic energy to the ink within the chamber;
- wherein the ink contains metallic particles, and wherein the at least one ultrasonication assembly is configured to reduce the size of the metallic particles before delivery of the conditioned ink to the print head, wherein the print head is configured to deliver the conditioned ink having the reduced metallic particles onto a work piece.

10. The apparatus of claim **9**, wherein the ultrasonication mechanism comprises an ultrasonic probe assembly.

11. The apparatus of claim **9**, wherein the ultrasonic energy has a characteristic frequency range of about 20 kHz to 400 kHz.

12. The apparatus of claim **9**, wherein the ink contains dissolved gas, and wherein the energy source is configured to degas the ink, to improve jetting of the ink from the print head onto a work piece.

13. The apparatus of claim **9**, wherein the ink contains agglomerated particles, and wherein the energy source is configured to deliver sufficient ultrasonic energy to the ink reduce the size of the agglomerated particles.

14. The apparatus of claim **13**, wherein the reduced size of the agglomerated particles prevents clogging of at least a portion of the print head from the ink.

15. The apparatus of claim **9**, wherein the apparatus is configured to contain the ink in the chamber for a time period that is sufficient for any of ink degassing or breakdown of particles.

16. The apparatus of claim **9**, wherein the ink contains dissolved gas and particles, and wherein the energy source is configured to degas the ink and to reduce the size of the particles.

17. A process, comprising the steps of:
- providing an ultrasonication mechanism, wherein the ultrasonication mechanism comprises
  - a body comprising
    - a chamber defined therein,

an inlet port extending into the chamber for receiving ink from an ink supply station, and

an outlet port extending from the chamber for transporting ink from the chamber to a print head, and

an energy source extending into the chamber for delivering ultrasonic energy to ink within the chamber;

delivering ink from a ink supply station to the chamber through the inlet port;

applying ultrasonic energy to the ink within the chamber to condition the ink;

transferring the conditioned ink from the chamber to a print head through the outlet port; and

applying at least a portion of the conditioned ink to a workpiece;

wherein the ink contains metallic particles, and wherein the at least one ultrasonication assembly is configured to reduce the size of the metallic particles before delivery of the conditioned ink to the print head, wherein the print head is configured to deliver the conditioned ink having the reduced metallic particles onto a work piece.

18. The process of claim **17**, wherein the ultrasonication mechanism comprises an ultrasonic probe assembly.

19. The process of claim **17**, wherein the ultrasonic energy has a characteristic frequency range of about 20 kHz to 400 kHz.

20. The process of claim **17**, wherein the ink contains dissolved gas, and wherein the energy source is configured to degas the ink, to improve jetting of the ink from the print head onto a work piece.

21. The process of claim **17**, wherein the ink contains agglomerated particles, and wherein the energy source is configured to deliver sufficient ultrasonic energy to the ink reduce the size of the agglomerated particles.

22. The process of claim **21**, wherein the reduced size of the agglomerated particles prevents clogging of at least a portion of the print head from the ink.

23. The process of claim **17**, wherein the ultrasonication mechanism is configured to contain the ink in the chamber for a time period that is sufficient for any of ink degassing or breakdown of particles.

24. The process of claim **17**, wherein the ink contains dissolved gas and particles, and wherein the energy source is configured to degas the ink and to reduce the size of the particles.

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